Accelerator Division Report

James B. Murphy
Associate Chair for Accelerators

Organization and Mission

The NSLS Accelerator Division (AD), headed by James B. Murphy, is organized into two sections: the Linear Accelerator (Linac) section, headed by Xijie Wang, and the Storage Ring & Insertion Device section (SR & ID), headed by Boris Podobedov. The AD staff consists of ten accelerator physicists, two engineers, three technicians, and four postdocs.

The NSLS Accelerator Division has a four-part mission:

- To ensure the quality of the electron beam in the existing NSLS booster and linear accelerator, and the x-ray & vacuum ultraviolet (VUV) storage rings
- To participate in the NSLS-II project, in particular the design of the storage ring and injection system
- To operate the Magnet Measurement Lab (MML) and the Source Development Laboratory
- To perform fundamental research and development in accelerator and free-electron laser physics

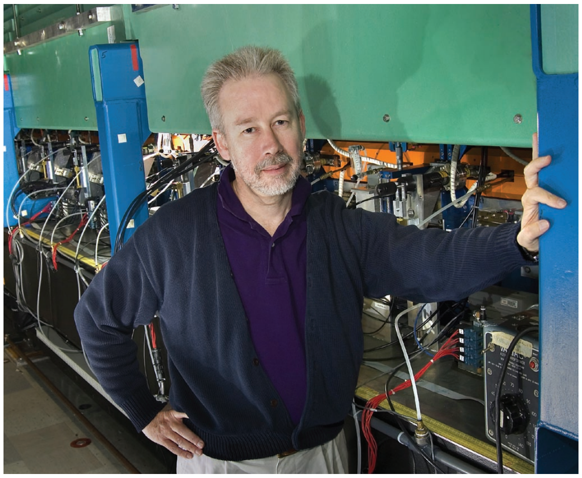
2005 Activities

Storage Ring & Injection System Improvements

Both storage rings have seen a steady rate of improvements in 2005. Several new or upgraded diagnostics, including electron beam profile imaging hardware and a turn-by-turn beam position monitor for injection studies, have been made operational in the x-ray ring. Machine studies took place to better understand and improve the injection process into the rings. Additional work has been done to better calibrate the x-ring lattice model, specifically to improve the control of the horizontal-vertical coupling and vertical dispersion. Machine studies were also performed to prepare for the installation of the new X25 undulator in January 2006.

One activity that brought an immediate improvement to the VUV ring users was the fine-tuning of the lattice, which resulted in a beam lifetime increase. Using the "Middle Layer" software tools incorporated into the NSLS control system last year, the VUV ring symmetry was restored by correcting the quadrupole settings and adjusting the revolution frequency. With the restored periodicity, the lattice has a 15-20% higher lifetime, depending on the ring current.

A task force on "Storage Ring Closed Orbit Measurement, Reproducibility, Stability & Feedback" was formed to develop a plan to provide improvements on orbit stability. The task force drew upon the experimental and theoretical expertise of the Accelerator, Operations & Engineering and User Science divisions. Its objective was to determine the factors that influence beam stability and reproducibility in the x-ray and VUV storage rings, determine the present performance of related systems, and make recommendations for improvements to these systems, up to the state-of-the-art. In the course of their work, the task force systematically examined the requirements of the users, the status of key subsystems, such as beam position monitors, orbit feedbacks, orbit correction algorithms, and the noise sources that degrade beam stability. A report of the task force's findings and recommendations is being prepared and those recommendations will be followed up on in the coming year.



Tremendous progress was made in FY05 to improve the NSLS injection system. Working in collaboration with the Operation & Engineering Division (OED), the beam profile monitors, wall current monitors, and synchrotron light monitor for the NSLS linac and booster were successfully upgraded. Those newly upgraded diagnostic tools are now being used to improve the injection efficiency and reduce beam loss. An RF klystron was successfully re-built by Communications Power Industries (CPI) to ensure that the NSLS linac has sufficient spare klystrons for future operations.

Magnet Measurement Laboratory

During the December 2005 shutdown, the existing 15-year-old X25 hybrid wiggler was replaced by a new, state-of-the-art, cryo-ready, in-vacuum “mini-gap undulator” (MGU), optimized for a dedicated macromolecular crystallography program. The X25 MGU is expected to provide X25 with between 2 and 30 times brighter x-ray beams over its entire tuning range, compared with the old X25 wiggler. It will also be substantially brighter, with better spectral coverage than the previous MGUs at X13 and X29. The mechanical and vacuum system was designed and fabricated by Advanced Design Consultants, Inc. of Lansing, NY; the magnet arrays were assembled at NSLS. The new MGU’s one-meter-long hybrid permanent magnet structure has a period of 18 mm, a minimum operating gap of 5.6 mm, and a peak on-axis design field of 0.91 T. The device will provide continuously tunable spectral coverage from 1.9 to 20 keV, using the fundamental, 2nd, 3rd, 5th, and 7th harmonics. We used a new high-remanence, high-temperature grade of NdFeB developed for hybrid car motors (NEOMAX 42AH) with Br = 1.3T and Hcj = 24 kOe at room temperature. The high intrinsic coercivity (Hcj) allows the undulator to be baked to 100 ºC without a loss of magnetization for ultra-high vacuum (UHV) compatibility. Baking under vacuum in the lab for half a day at 90 ºC showed only a 0.4% decrease in the peak field, and an additional five-day 85 ºC bake showed negligible additional demagnetization. The final pressure after cool-down was less than 5x10-10 torr, well within x-ray ring requirements.

The new MGU design incorporates several novel features, the most important being a provision for cryo-cooling the magnet arrays to 150 K. This will increase the remanence (Br) of the NdFeB magnets to about 1.45 T and raise the peak field to 1.0 T, thereby increasing the tuning range of all harmonics by 11%, as well as increasing the source brightness at some key photon energies.

Proud X25 team surrounding the new mini gap X25 undulator

To minimize stress and deformation of the magnet support beams during welding of the cooling channels, a low-temperature “friction stir welding” technique was used for the first time in a UHV device. The cooling channels proved to be vacuum-tight under repeated cryogenic cycling and baking. A provision for stress-free thermal expansion and contraction of the magnet support structure was also demonstrated during the thermal cycling.

A novel gap-measurement system using a commercial, high-precision, LED-based optical micrometer was incorporated to back up the linear encoders and to correct for gap changes due to differential contraction during cryogenic operation. The system optically monitors the magnet gap through viewports at either end of the MGU, ensuring a gap accuracy of ±2 micrometers.

Magnetic measurements were performed using both pulsed wire and Hall probe mapping. A pair of full-length, rectangular Helmholtz coils was added to the exterior of the vacuum chamber to compensate for Earth’s field and to cancel a small systematic dipole error in the magnet array. These coils will be powered by one of the existing end-pole supplies from the old X25 wiggler. Despite very little time for trajectory, multipole, and phase error shimming, we achieved an RMS phase error of 2.5 degrees (sufficiently low to assure good spectral quality up to the 7th harmonic) and met the x-ray ring’s multipole tolerances.

The new X25 MGU was completed, tested, measured, and shimmed on schedule, thanks to the outstanding efforts of NSLS staff members from all divisions, who worked many nights and weekends to make it happen. Most of them can be seen in the photo above.

NSLS-II Machine Design

The NSLS-II storage ring is the future of the NSLS, and it will provide unprecedented high-brightness photons to the user community. The AD staff worked in collaboration with the OED staff to produce the pre-conceptual machine design, which served as the technical basis for achieving “Critical Decision Zero” status for the NSLS-II project in August 2005.

Source Development Laboratory (SDL)

The Source Development Laboratory is a platform for the development and applications of new radiation sources, such as free electron lasers and coherent terahertz (THz) radiation. Funding was obtained from the Office of Navy Research to pursue the development of laser-seeded free electron amplifiers in the 0.8 - 1.0 micron range. The SDL has also measured a record 100 microjoules per pulse of THz radiation, which will be used for materials science applications by BNL and external users.